The Institute of Physics

BULLETIN

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The Bulletin is published by The Institute of Physics for circulation to its members ; copies should not be placed in libraries.

Notices to Members

Dr. S. Whitehead

As the *Bulletin* was going to press, we learned with the deepest regret of the sudden death of Dr. Stanley Whitehead on May 5 at the early age of 53 years. Dr. Whitehead had been Honorary Treasurer of the Institute since 1952. A tribute to him will appear in the June *Bulletin*.

Announcements of Vacancies—Use of Box Numbers

From time to time the suggestion has been made by members that the Institute should not permit the use of box numbers in announcements of vacancies published in the *Bulletin*. The Board has now accepted this suggestion ; in future no advertisement will be accepted for publication in the *Bulletin* unless the name of the firm offering the vacancy is disclosed.

Conference on the Physics of Nuclear Reactors

A few places for members of the Institute are still available at the Conference on the Physics of Nuclear Reactors to be held at the Institution of Electrical Engineers on July 3-6. The full programme was published in the February *Bulletin*. Members who wish to attend should apply immediately for a form of application.

Royal Aeronautical Society and Stress Analysis Group — Joint Conference

The Institute's Stress Analysis Group has arranged a joint conference with the Royal Aeronautical Society. This will be held at

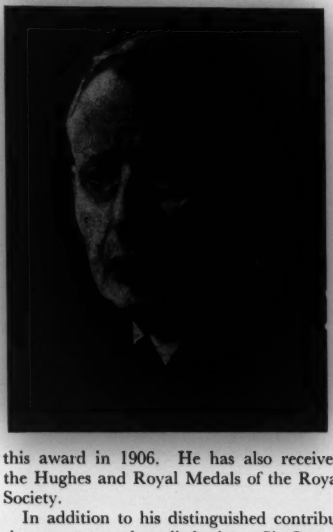
the College of Aeronautics, Cranfield, from September 19-21. Details will be circulated in due course to members of the Group ; other members of the Institute who would like to have these details should notify the Deputy Secretary.

ELECTION TO HONORARY FELLOWSHIP

Notice is hereby given that in accordance with By-Law 9, the Board has nominated and subsequently confirmed the nomination of Sir George Paget Thomson, M.A., Sc.D., LL.D., F.Inst.P., F.R.S., *Nobel Laureate*, for election as an Honorary Fellow of the Institute, and that the result of the ballot will be declared at the 36th Annual General Meeting. Ballot papers will be circulated later to Fellows and Associates.

B. P. DUDDING,

Honorary Secretary.



Sir George Thomson, son of Sir Joseph Thomson ("J. J.") the Institute's first Honorary Fellow and subsequently President, has been Master of Corpus Christi College, Cambridge, since 1952. After graduating at Cambridge he became a Fellow and lecturer of Corpus Christi College in 1914. During the first World War, after service in France, Sir George worked on problems of aeronautical research until his return to Cambridge in 1919. In 1922 he was appointed Professor of Natural Philosophy in the University of Aberdeen and in 1930 succeeded the late Professor Callendar as Professor and Head of the Department of Physics in the Imperial College of Science and Technology, London ; it was from this post, after twenty-two years, that he went to the Mastership of Corpus Christi.

Sir George was awarded the Nobel prize for Physics in 1937, his father having received this award in 1906. He has also received the Hughes and Royal Medals of the Royal Society.

In addition to his distinguished contributions to pure and applied science Sir George has found time to serve on various Government advisory committees and was Chairman of the first British Commission on Atomic Energy. He has been Scientific Adviser to the Air Ministry and to the British Delegation to the United Nations Atomic Energy Commission.

Vol. 7, May, 1956

Physics and Medicine: Recent Progress in Glasgow

By J. M. A. LENIHAN, M.Sc., Ph.D., F.Inst.P.

(*Regional Physicist, Western Regional Hospital Board*)

PHYSICS and physic have long been associated in fruitful collaboration for the relief of suffering and the advancement of knowledge. In days gone by, the doctor was often the only man of learning who received any scientific training. Galileo started his career as a medical student, William Gilbert was Queen Elizabeth's physician and Joseph Black, whose researches in heat laid the foundations of the Industrial Revolution, was Professor of Medicine, first in Glasgow and then in Edinburgh; during the nineteenth century, Young and Helmholtz achieved renown both as physiologists and as natural philosophers. In our own time, physicists have made a notable contribution to the progress of radiation therapy by establishing systems of units, methods of measurement and a host of useful techniques to facilitate the employment of X-rays, radium and radioactive isotopes in the treatment of disease. Many centres have quite large departments devoted to activities of this kind and valuable work has been done in the application of physics to other branches of medicine and surgery by individuals or teams stationed in specialized hospitals and research institutions.

The Western Regional Hospital Board, observing these developments, has recently established a central laboratory for the practice of clinical physics, in its widest interpretation, throughout the West of Scotland. Previously existing facilities were slight, consisting only of one-man departments in two of the teaching hospitals, and the new organization had to grow from very small beginnings. The department's activities are still expanding quite rapidly but a general account of what has been attempted during the last three years may be interesting.

The first problem to be faced, after the establishment of the department had been approved, was the acquisition of a building. Many possibilities were considered but no progress was made until early in 1953 when premises became available at West Graham Street near the centre of Glasgow. Here a three-storeyed block of eccentric architecture, formerly the Out-patient Department of the Royal Hospital for Sick Children,

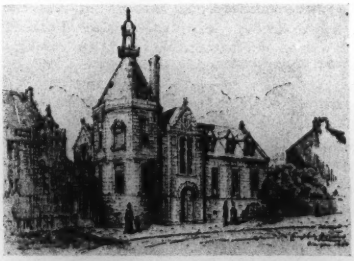


FIG. 1. *An old drawing, showing the Dispensary shortly after it was opened in 1868. This building, and another block added in 1897, now accommodates the Regional Physics Department.*

was allocated for use as a Regional Physics Department. The building, though structurally sound, was superficially revolting and thoroughly uncomfortable when a staff of three physicists and two technicians started work in October, 1953. A programme of renovation was carried out in 1955, transforming the dismal old building into a bright and busy laboratory, with

7,000 square feet of useful floor space, allocated in the following way :

Teaching and students accommodation	2,300 sq. ft.
Workshops	1,300 sq. ft.
Research Laboratories	1,100 sq. ft.
Staff laboratories and offices	900 sq. ft.
Stores	500 sq. ft.
Administration	500 sq. ft.
Isotope Laboratories	400 sq. ft. (with a further 1,000 sq. ft. in various hospitals).

The staff of the department now includes eight physicists, two chemists and eight technicians, with several more appointments to be made during 1956. Its activities fall mainly into the following categories.

TEACHING

Medical graduates wishing to specialize in diagnostic or therapeutic radiology usually read for the diplomas awarded by the Royal College of Surgeons of England and the Royal College of Physicians of London. The first part of the two-year course is devoted to physics and classes assemble each year for lectures, laboratory training and demonstrations dealing with various technical aspects of radiology. Most of the students come with open minds, having readily forgotten the physics which they learned for the 1st M.B. examination, but they absorb a great deal of fresh knowledge in a few months.

Instruction at a less advanced level is given to radiographers. In Scotland, most of the young women who enrol for this course have studied little science and no physics. It is therefore necessary to administer the rudiments of electrical science in a patient fashion before explaining their applications in the X-ray department. Here again, the enthusiasm of the students often compensates for lack of knowledge and a reasonably satisfactory result is usually produced.

The highlight of the department's teaching activity is the isotope course, organized in conjunction with the Glasgow University Veterinary School and the Western Infirm-

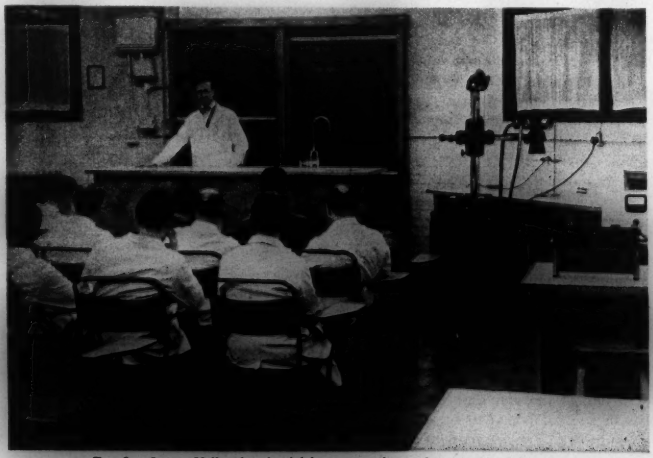


FIG. 2. *Lecture Hall and students' laboratory, made out of a patients' waiting room.*

ary. The object of this course is to describe the biological applications of isotope techniques. The first group of ten eminent and industrious students from hospital and University departments, led by the Regius Professor of Midwifery, assembled in September, 1955, for a fortnight's very hard work and further classes are to be held twice a year. Seven of the original students are now occupied with research projects using radioactive isotopes in their own departments.

FIG. 3. *An automatic sphygmomanometer, built in the department and used in hospitals for continuous recording of a patient's arterial blood pressure.*

WORKSHOP SERVICES

Many branches of clinical practice and research make use of electronic instruments or other apparatus requiring the help of the physicist for its design and maintenance. When this equipment is commercially available, the physician or surgeon who is going to use it can seldom assess the technical merits of the different alternatives offered to him. Often the desired instrument is not offered by any manufacturers or is unacceptable because of high cost or slow delivery. In such circumstances the Regional Physics Department is frequently asked for advice or for more positive assistance in the design and construction of apparatus for use in a hospital. In this task, the first essential is a reference library of books, journals and catalogues, covering a wide range of subjects. Constructional work is done in three places—the mechanical workshop (with a welding shop and a metalwork room), the electronics workshop and the vacuum laboratory (with equipment for glassblowing and sputtering as well as a range of conventional pumping and measuring devices).

ISOTOPES

The department is responsible for the technical supervision of work with radioactive isotopes throughout the region. Materials bought in bulk from Harwell and Amersham are dispensed in a newly built laboratory for issue to the various clinical teams. In this way a considerable financial saving is made (the cost of most isotopes is a few pounds for the first millicurie and a few shillings a millicurie thereafter) and a uniform standard of accuracy is achieved in the doses administered to patients. The department receives regular consignments of nine radioactive materials—^{24}Na, ^{32}P, ^{35}S, ^{51}Cr, ^{59}Fe, ^{131}I, ^{132}Te, ^{165}Zn and ^{198}Au at a total cost of about £1,500 per year. Detachments of staff are stationed in two large hospitals to help in the isotope service and the same facility will shortly be extended to a third hospital.

Radioactive isotopes are extensively used as weapons of clinical investigation, though nature has put formidable obstacles in the path of this enterprise. The four elements, hydrogen, carbon, nitrogen and oxygen, which make up 96 per cent of the human body have no isotopes suitable for simple routine tests of the kind required in a hospital. A lot of less common elements occur in radioactive varieties with useful properties which have been exploited in two principal ways. The first technique is to introduce a few microcuries of radioactive material into the patient (by mouth or by way of a vein) and to study its subsequent progress

FIG. 4. *Source and target assembly of the neutron tank. Four antimony-beryllium sources made at Harwell are submerged in water, giving a thermal neutron flux of about 10^5 n/sq. cm/sec. in the target zone, where suitable materials are irradiated, producing short-lived isotopes for teaching and experimental purposes.*

by direct exploration with a counter (for a γ-emitter) or by the assay of samples taken from the body (for a β-emitter). The other important application involves the administration of massive doses—several millicuries—for the treatment of disease. There are, unfortunately, very few conditions in which isotopes have any advantage over more conventional therapeutic agents.

In all of this work the physicist has interesting responsibilities. Preliminary discussion and calculation with the physician or surgeon is necessary to show whether a proposed investigation is technically feasible, having regard to the safety of the patient and the sensitivity of the counting apparatus. An application is then submitted, jointly by the clinical director of the project and the collaborating physicist, to the Medical Research Council, which regulates the use of radioactive isotopes for human and animal investigations. The proposal is examined by an Advisory Panel of expert referees, whose approval is necessary before the work can be started. The next step is to arrange for the supply of the isotopes required and to allocate staff and equipment for carrying out measurements in the hospital or in the department. As the experiment proceeds, regular consultations are held to assess results and plan the next stages. Finally, the physicist is responsible for the disposal of unused material and of any radioactive waste produced during the investigations.

A number of research and development projects are under way. Some have been suggested by clinical colleagues in the hospitals and others, of less urgent practical importance, have been initiated in the department. A few examples will serve to illustrate the scope of these endeavours.

RESPIRATORY PHYSIOLOGY

The department has become involved in a large programme of research directed by the Regius Professor of Midwifery. This work is concerned with the study and treatment of respiratory deficiencies in the newborn—now the commonest cause of death in the neonatal period. The physical problem here is that the infant's lungs do not absorb enough oxygen to keep him alive and its solution requires a modicum of subtlety. It is not enough to put the baby into a mechanical respirator, delivering regular doses of air, because a tiny child does not breathe naturally at regular intervals. He can do without air for quite a long time and often prefers to take a few gasps now and then, with irregular intervals between each effort. When put into a respirator which imposes a different rhythm, he struggles and perhaps dies. The solution, devised in London by Professor Ian Donald and brought to Glasgow in prototype form eighteen months ago, is a servo-respirator in which the baby's feeble efforts at inspiration are detected, changed into electric signals and used to control the supply of air or oxygen at suitable pressure from a storage cylinder. In this way the child takes a breath whenever he likes, but the amount of oxygen received is not limited by his own feeble strength.

This machine has now been produced in a rugged form incorporating a number of novel electronic, optical and pneumatic devices and is in regular use at a maternity hospital. A replica has been made for a hospital in England and further production, on a commercial scale, is being arranged.

A large effort is being devoted to the design of transducers and display systems for recording fluid pressures in body cavities. A remarkable achievement was made a few weeks ago when apparatus made in the department was used to measure the negative pressure established during the first breath of life. The breathing pressure in an adult is 3 or 4 cms. of water, but a newborn baby, with his first gasp, generates a suction equivalent to 60 or 70 cms. of water.

PROPORTIONAL COUNTERS

In counting systems using geiger tubes or scintillating crystals, many of the available particles and quanta are not recorded, because of geometrical, electrical or optical limitations. The overall efficiency of the counting equipment used in biological tracer investigations is seldom more than a few per cent and, for isotopes such as ^{35}S and ^{51}Cr which emit soft radiations, may be even less. A proportional counter will detect β-particles with high efficiency and a device of this kind, suitable for use in a hospital laboratory, is now being built in the department. The counter itself presents little difficulty but the electronic accessories, including the anti-coincidence network to reduce the background counting rate, are quite elaborate. The present model has the same background as a popular commercially-built scintillation counter but about ten times the detecting efficiency for ^{131}I and ^{35}S. With this improvement, many isotope investigations will become possible with safety for the first time and others will take on a greater accuracy.

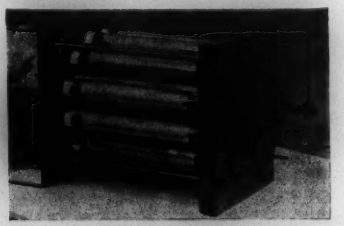


FIG. 5. *A proportional counter built in the department for the assay of feebly radioactive samples of biological material. The counter is surrounded by a ring of Geiger tubes in an anti-coincidence circuit, to reduce the cosmic ray background counting-rate.*

ACTIVATION ANALYSIS

Small samples of hair, skin or nail exposed to neutron bombardment in a reactor will emerge with a measurable radioactivity, mainly due to isotopes of sodium and—rather surprisingly—arsenic. This element, though present to a very small extent in normal tissues, has a large cross-section for neutron capture to form the short-lived ^{76}As. A single hair, with the normal arsenic content of about one part per million will, after irradiation for 24 hours in the Harwell pile, contain enough ^{76}As to give a count rate of 50-100 counts per minute in a liquid sample geiger tube of standard design. (To achieve this result it is necessary to do a simple chemical extraction of arsenic from the irradiated hair—otherwise the activity recorded is largely due to ^{24}Na).

Activation analysis enables arsenic and a few other elements to be detected with a sensitivity beyond the reach of chemical methods and the technique is being applied to several clinical problems, including the study of arsenical poisoning and of industrial dermatitis. Other investigations are being made in collaboration with the Department of Forensic Medicine at Glasgow University and the Cancer Research Department at the Royal Beatson Memorial Hospital.

X-RAY AND RADIOTHERAPY SERVICES

The department provides technical help of many kinds to the X-ray and radiotherapy services. The nature of this work will be familiar to many readers of the *Bulletin* from Mr. R. G. Wood's detailed description in the June, 1954, issue.

SILVER RECOVERY

In an X-ray dark room, substantial quantities of silver are released from films in the fixing tank, combining with the hypo and thereby inactivating it. By gentle electrolysis of the solution, the silver may be collected on an electrode while the fixing agent is regenerated for further use. This delightful process evokes much admiration from our administrative colleagues, for it makes an impressive profit. An electrolytic unit installed in a moderately-sized hospital at a cost of £30 will collect silver to the value of £100 every year and will save a further substantial sum by extending the life of the fixing bath. The department keeps a stock of apparatus for issue to hospitals and encourages the adoption of this lucrative practice.

ACOUSTICS

Since the inception of the National Health Service a great deal of clinical work has been done in the diagnosis and correction of hearing defects. This work raises interesting physical problems, involving the establishment of acoustical standards for the delineation of hearing thresholds in normal subjects and in deaf patients. The instruments used for routine testing of auditory acuity require frequent calibration to maintain their accuracy and the hearing aids issued to patients are returned at a steady rate for replacement or repair. It is hoped shortly to establish an acoustics laboratory within the department to deal with these and other technical duties associated with the hearing aid programme.

Another task, partly acoustical in nature, is the design of a staff location system. Every hospital receives by telephone a lot of enquiries which need the immediate attention of particular members of the medical or administrative staff. The problem of finding an individual who may be anywhere in a large hospital and bringing him to the telephone is sometimes tackled by the installation of loud speakers (which disturb the patients) or coloured lights (which do not give complete coverage of the building). The commonest practice is to use nurses and other highly-trained people as messengers. Even this extravagance is of little avail ; one major hospital in Glasgow is isolated for an appreciable period of every weekday when the telephone switchboard becomes choked with calls awaiting attention.

Experiments have been in progress for some time on a simple calling system built in the department. A loop of wire fixed to the outside of the building is connected to an oscillator supplying a few watts of power. Each member of the staff carries in his pocket a small receiver consisting of an iron-cored coil, a two-stage transistor amplifier and a midget loud speaker. When the loop is energized, the magnetic field throughout the building is enough for an audible message to reach the person being called. The department's efforts here are in no way original, for the principle is quite well known, but manufacturers have been slow to realize its obvious application in hospitals. Three firms have recently started commercial development of an improved system, with selectivity adequate for 50 to 100 channels. Plans are being made for a small piece of operational research to study the efficiency of hospital communication systems and to assess the merits of the magnetic induction device by full-scale trials over a period of months.

The National Health Service in general, and its laboratory facilities in particular, are now being uncomfortably strained by the conflict between uncontrolled demand and limited resources. In these circumstances the department has had to face many difficulties, both administrative and technical. It is now securely established and similar organizations are being planned in other regions. Such developments are to be welcomed for, in a world dominated by fissiles and missiles, the clinical physics department is a little island of compassion where scientific knowledge and skill can be applied in a wholly benevolent way to the most charitable of all man's enterprises.

Vol. 7, May, 1956

The Problem of Tone Reproduction in Offset Lithography*

By V. G. W. HARRISON, Ph.D., F.Inst.P., F.R.P.S.

(*Printing, Packaging & Allied Trades Research Association*)

OFFSET LITHOGRAPHY is to-day one of the most important printing processes. Although it has many advantages, it nevertheless suffers from two serious drawbacks, the first of which is the thinness of the ink film applied to paper. On account of this thinness, the optical density of the applied film rarely exceeds 1·4, corresponding to a reflection factor of about four per cent, and the maximum depth of tone is a dark grey rather than a good black. Some improvement has been made in this direction recently, particularly in the U.S.A., but a discussion of the means adopted lies outside the scope of this article.

The second drawback is that it is impossible to convey the effect of half-tones by varying the amount of ink applied to paper. The ink is either transferred at full strength—such as it is—or not at all. Consequently the effect of half-tones can only be reproduced by splitting up the continuous tone image into dots too small to be resolved individually by eye, the relative sizes of these dots governing the depths of tone perceived. The problem of tone reproduction is to ensure the correct sizes of dots throughout the scale of tones from white to black. This problem is a very real one since the relative dot sizes resulting from the methods of working generally practised at present are far from correct and a serious distortion of the tone values becomes apparent. This distortion reveals itself in the main by a lack of contrast in the highlights and excessive contrast in the deeper middle tones, so that the print has a washed-out appearance lacking in highlight detail. These faults are apparent in monochrome but are even more evident in colour. Improved results are normally obtained only by a costly and none too satisfactory process of hand retouching, elimination of which would bring about a reduction in costs as well as improved quality of work.

Decomposition of a continuous tone image into dots is effected by the use of a half-tone screen. Until recent years the type of screen almost universally adopted for this purpose has been the glass cross-line screen. This consists of a piece of good quality glass which has been engraved with a series of parallel channels, afterwards filled in with a black opaque substance. The width of the opaque bands so formed is usually about the same as the distance between them—that is, the opaque and clear spaces in the glass are in the ratio 1 : 1. However, screens in which these widths are as 2 : 3, 5 : 8, or other ratios are to be encountered. The complete screen is made by cementing together two such engraved plates at right angles so that the result is a coarse two-dimensional diffraction grating normally having between 50 and 150 lines to the inch, according to the type of work to be reproduced and the quality of paper selected for printing.

The glass cross-line screen is generally used at a distance of 7-10 mm. from the surface of the photographic plate, but the distance is subject to some variation accord-

* A talk given to the London and Home Counties Branch of the Institute on November 9, 1955

ing to the camera extension, the aperture of the camera lens and the screen ruling. The disposition of the camera lens, screen and photographic plate is in fact closely analogous to that of sun, moon and earth during a total eclipse, as shown in Fig. 1, the upper part of which will be familiar

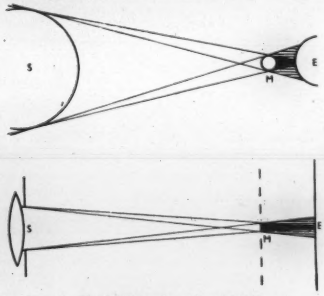


FIG. 1. *(a) Total eclipse of sun (not to scale) ; (b) Action of cross-line screen (not to scale).*

to most readers. On account of the large size of the sun, the region of complete shadow (umbra) thrown by the moon is restricted to the cone shown in solid black. Within the larger cone shown shaded (the penumbra) the eclipse is only partial and the intensity of light received at any point depends upon how far the point falls within the penumbra. It is well known how closely eclipse data calculated in this way from geometrical optics tally with the observed facts. The situation in the process camera (shown in the lower part of Fig. 1) appears at first sight to be similar. Corresponding to the illuminated disc of the sun S is the illuminated diaphragm of the camera lens. An opaque element of the screen is the analogue of the moon and a photographic plate that of the earth's surface. Usually matters are so arranged that the tip of the umbral cone just reaches the surface of the plate, and the intensity of illumination reaches a minimum at this point, rising to a maximum at a point directly under the mid point of a transparent screen opening. The dot formation can be explained qualitatively on this basis, but it is easily shown that diffraction plays a substantial part in the result. Better quantitative agreement with practical results is shown by a recent version of the diffraction theory[1] and the light distribution worked out for a practical case from this theory is shown in Fig. 2. This shows the lines of constant relative intensity of illumination (isophotes) at the surface of the photographic plate behind the half-tone screen for certain specified conditions. The diagram is symmetrical about each of the lines AB, BC, CD and DA and can be repeated indefinitely. The point of maximum intensity falls immediately behind the centre of a screen opening and the intensity decreases from this point in all directions ; however, it nowhere reaches zero intensity, as predicted by the simple penumbral theory.

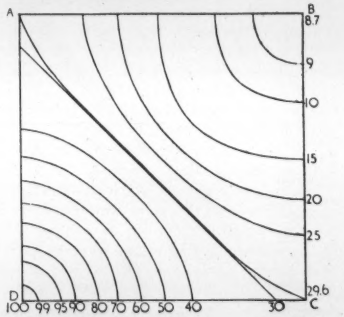


FIG. 2. *Isotopes for 5·8 ratio cross line screen. 133 lines/inch. Thickness of cover glass 2·5mm. Distance of rear surface to plate 7·0 mm. Camera extension 122 cm. Square stop of side 11.6 mm. parallel to screen rulings. Mean wavelength of light 530.*

A plate of normal contrast exposed behind the half-tone screen would merely record these intensity variations as density differences and the whole object of the exposure would be lost. The exposure is therefore made on an emulsion of the highest possible contrast developed in an appropriate developer. What is wanted is a plate-developer combination which will give no density at all until a certain critical

exposure is reached and giving full density immediately this critical exposure is exceeded. Such an ideal combination is unknown, but modern dry plates for photolithography used in accordance with the makers' instructions give thereto a satisfactory approximation.

Imagine now that the plate receives an exposure such that the threshold is exceeded only at the point of maximum intensity (100 per cent). On development there will be (in theory) a minute dot immediately under the centre of a screen opening, the rest of the negative being clear glass. If the exposure of a second plate is increased to $\frac{100}{90}$ that of the first, the area enclosed by the 90 per cent isophote will be blackened after development, the rest of the plate remaining clear : the result is a larger (but still small) circular dot in a clear background. By continuing this reasoning we find that the originally circular dots increase in size with increasing exposure, becoming square with rounded corners. When the exposure rises to $\frac{100}{30}$ that of the original, the dots (now sharply square) join up at the corners to form a chess board pattern. Finally, when an exposure of $\frac{100}{8{\cdot}7}$ of the original is reached, the entire negative is blackened and greater exposures have no further effect.

If a continuous tone copy is photographed under uniform illumination, the exposure received by any part of the plate will be proportional to the luminance factor of the corresponding part of the original. Since the area enclosed by each isophote can be estimated by means of a planimeter, it becomes a straightforward task to calculate the relation which should exist between the luminance factor of the original and the luminance factor of the screen positive made from it, on the assumption that the shapes of the isophotes are preserved and the dark and clear parts are of infinite and zero density respectively. (More will be said about these assumptions later.) Fig. 3 shows the result derived from Fig. 2. Ideally a linear

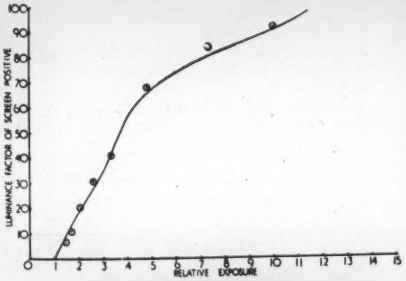


FIG. 3. *The curve is derived from theory but some experimental points are shown encircled.*

relation should hold between the luminance factors of original and reproduction. Fig. 3 shows that this is not so for the example considered and further examination has shown that whatever may be the settings of the process camera and half-tone screen, the final result is always of the type shown in Fig. 3, having too little highlight contrast compared with the shadow contrast.

There are various methods of printing by lithography. One of the most widely used is the deep etch offset process, in which a common practice is first to make a screen negative from the original. This screen negative usually has grossly faulty tone values. A screen positive is made by contact from the negative, but the dot sizes in the two plates do not correspond perfectly. This is because the photographic emulsions used do not show the infinite contrast postulated and the resulting dots, instead of having perfectly sharp outlines, have slightly soft fringes : the size of dot obtained by contact printing thus depends to some extent upon the conditions of exposure and development. In general, the density of the screen positive obtained by contact printing is somewhat greater than simple theory would predict.

The contact positive is printed down on to zinc or aluminium and finally the image so produced is inked and the ink transferred to paper via a rubber blanket. There is no straightforward relation between the den-

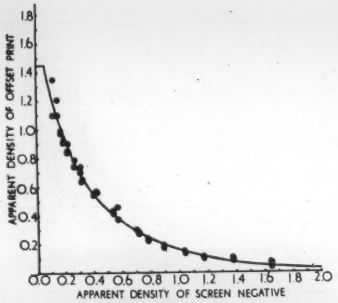


FIG. 4. *Relationship between densities of screen negative and final print on paper.*

sities of the various tones of the contact positive and the corresponding tones of the final print. As already explained, the optical density of the ink film on paper is rarely above 1·4 however high the density of the screen positive may be. Further, if the print is made on translucent paper, Yule and Nielsen[2] have shown that the half-tone dots are effectively larger than their geometrical area on account of light scattering within the paper. Taking these complications into account, Harrison, Mitchener and Lawson[3] have been able to establish a relation between the density of the screen negative and the density of the offset print obtained under average commercial conditions. This relation is shown graphically in Fig. 4 and can be used to assess the performance of existing screens. Fig. 5 shows a typical result, in which the density of the offset print is plotted against the density of the original. The contrast in shadows and mid-tones is shown to be fairly good, but the extreme highlight contrast is one fifth or less than of the shadows. This accounts for the lack of detail in the highlights and flat appearance of most unretouched lithographic prints.

It is clear that the action of the glass cross-line screen is merely to produce variations in intensity of the light reaching the photographic plate placed behind it. The same result can be obtained by placing a piece of film in optical contact with the plate, provided the film has densities graded so as to produce variations in intensity similar to those given by the cross-line screen. Such films are known as contact screens and are available commercially. While it does not appear that the cross-line screen can ever be made to give a satisfactory screen negative for offset (since the intensity distribution it is capable of giving is circumscribed by the laws of diffraction), the contact screen, on the other hand, can be made in theory to give any gradation desired. The commercial contact screens so far available do not, in fact, give tone reproduction importantly different from that afforded by the old glass screens. This has been due to their method of manufacture. By suitably choosing the gradation of vignette in the contact screens it should be possible to solve, at least approximately, the tone reproduction problem in lithography.

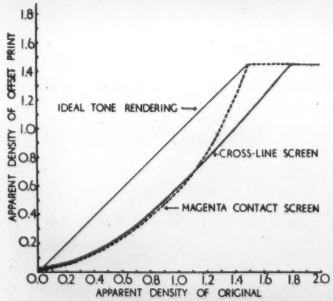


FIG. 5. *Tone rendering of commercial half-tone screens. (The "magneta contact screen" is one of the commercial screens at present available, not the experimental screen.)*

There are two main methods of preparing vignetted screens. The first is to etch or engrave channels or depressions in the surface of a sheet of transparent material and to fill these depressions with a coloured substance. The absorption of light at any point of the screen so produced then depends upon the depth of the depression at that point and the concentration of dye used in the filler. By suitably engraving the con-

tours of the channels, any desired type of vignette can be produced. There are, however, formidable difficulties to be overcome in making such small-scale engravings to the required degree of accuracy and generally an alternative photographic method is easier and preferable. In this method a sheet of photographic film is given an exposure which varies periodically over its surface in a determined manner. Numerous ways of giving the variable exposure exist, almost all of which are described in the patent literature. The film is developed to give either a neutral silver image, or, by the use of a dye coupling developer, a coloured dye image. Generally the exposure is such as to produce a series of parallel vignetted lines, and the screen is made by giving the film two exposures at right angles before development so that the final pattern is made from two sets of parallel vignetted lines intersecting at right angles.

Although in principle the gradation of a contact screen can be varied in any manner, in practice it is desirable to satisfy certain requirements which impose restrictions on the sizes and shapes of dots obtainable. If the photographic method of screen making is adopted, for example, it is convenient to make the screen by giving two separate exposures at right angles. The density at any point is then determined by the sum of the two exposures received at this point. Generally, the screen is required to be symmetrical, which means that the two exposures must be equal. This limits the variety of dot shapes and areas obtainable. Furthermore, it is desirable, though perhaps not essential, that the dot shapes in the screen negative should not differ radically from those given by conventional glass screens. If this is not so, the screen negatives will have an unfamiliar appearance and experienced lithographers will be reluctant to use them.

The problem of producing a contact screen suitable for offset lithography does not admit of a mathematically rigorous solution; but an approximate solution, sufficient for most practical purposes, has been found. Since the commercial development of such a screen is under consideration,

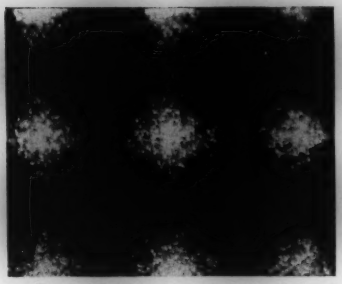


FIG. 6. *Experimental contact screen* (× *200*).

it is not permitted to publish full details at this stage. However, Fig. 6 is a photomicrograph of an experimental screen conforming as closely as possible to this solution. This screen has been found to give normal dot formation, but offset prints made from screen negatives prepared through it give nearly uniform contrast throughout the tonal range. Such a screen can be expected to effect a substantial improvement in the quality of lithographic prints. Fig. 7 shows the theoretical performance of the new screen, the calculated densities of the final print being plotted against densities of the continuous tone original. The ideal reproduction should reproduce exactly the tones of the original up to a density of 1·45, as shown by the dotted line. The calculated reproduction of the new screen is denoted

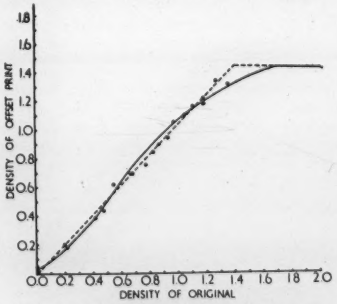


FIG. 7. *Tone rendering of experimental contact screen,*

by the continuous curve. Ideal tone rendering is not achieved, but deviations from the ideal do not exceed ten per cent at any part of the range and are less than one fifth of those found with screens available up to the present. The black solid circles are experimental points. They were obtained by making screen negatives from two step wedges through the new contact screen, making contact positives from the negatives, printing down these positives on to zinc by the deep etch process and printing the zinc plates by offset in the normal way. The circles represent the measured densities of tones in the final print plotted against the measured densities of the original. In practice, closer conformity to ideal tone reproduction has been obtained than theory would indicate.

It is possible that a closer theoretical approximation to the ideal may be found. It is easy to modify the screen so that close conformity to the ideal can be achieved over a limited part of the density range, but the deviations generally become worse elsewhere. The mid-tone densities are especially troublesome.

The screen described in this article does not require any modification to existing negative or platemaking technique. Only one exposure is required, but this must be carefully controlled. A supplementary exposure may be necessary if the density range of the original exceeds 1·4.

Several problems remain to be solved before the commercial production of these screens can be started, but the work is in hand. It forms part of a joint programme of research being undertaken by the Printing, Packaging and Allied Trades Research Association, Leatherhead, and the Stichting Instituut voor Grafische Techniek T.N.O., Amsterdam. It is pleasing to record this example of Anglo-Dutch co-operation.

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1. Harrison, V. G. W., *Phot. J.*, 1952, **92B**, p. 74.
2. Yule, J. A. C., and Nielsen, W. J., *Mod. Lithography*, 1951, **19** (9), p. 69.
3. Harrison, V. G. W., Mitchener, G. A., and Lawson, L. E., *J. Phot. Sci.*, 1955, **3** (4), p. 97.

Reviews of Books

LEHRBUCH DER EXPERIMENTAL PHYSIK : Vol. III. Optik und Atomphysik, Part I Wellenoptik

By L. Bergmann and C. L. Schaefer

Berlin : Walter de Gruyter and Co. Pp. 422. Price D.M. 32.

The textbook of which this is part of one volume, is intended for use in conjunction with academic lectures or for self-tuition. It is a workmanlike job of a standard approximating to that for an Honours degree in physics. The topics included are those which can be satisfactorily described in terms of wave-theory. Thus they include geometrical optics, though in this the treatment is almost exclusively by rays (a procedure justified early on in the book), interference, diffraction and the optics of bi-refringent crystals. Phenomena which must be described by quantum theory, such as light emission, fluorescence and luminescence, are not treated, but refraction, dispersion and reflection, which are fundamentally quantum phenomena but capable of description by electromagnetic wave-theory, are. As befits the general title of experimental physics the treatment is largely descriptive. There is a Victorian air about one or two of the figures, but where these are illustrations of apparatus, the older forms are probably better for teaching purposes than the modern stream-lined versions all totally enclosed. The substance of the book is quite up to date. It includes descriptions of Abbe's theory of the microscope, Zernike's phase-contrast method, anti-reflection coating, polarizing films of the " Polaroid " type, and even a brief account of what is meant by coherence. Among minor faults, some of the lettering on Fig. 20 is upside down and the reference numbers to some of the equations have been omitted.

E. W. H. Selwyn.

THE NUMBER-SYSTEM

By H. A. Thurston

London, Glasgow : Blackie and Son Ltd., 1956. Pp. 134 + viii. Price 15s.

The main concepts of mathematical analysis cannot be discussed without a firmly based understanding of the idea of number. Books on analysis usually start with the assumption that the reader is familiar with the rules of manipulation of the rational numbers p/q, where p and q are integers. These rules are the commutative and associative laws of addition and multiplication, the distributive law and the properties of the order relation. The fact that the rational number system is not closed to the operation of root extraction (the equation $x^2-2=0$, for example, having no rational solution) shows the necessity for the construction of the real number system, and the fact that the equation $x^2+2=0$, for example, has no real solution shows the necessity for the construction of the complex numbers. Having done this, the analyst is able to discuss convergence, continuity, differentiation and integration. The point of view of the algebraist is different. His interest lies in the structure of the number system as defined by its operations. The author of a book such as this has several choices to make. The first is the choice of starting point, the second is the choice of method, and the third the choice of balance between the analytic and algebraic approach. Finally there is the important question of the knowledge and experience assumed to be possessed by the reader. It is the opinion of the reviewer that the author has succeeded in resolving these difficulties in a very satisfactory way and has written an interesting and useful book.

The book is divided into two parts, each containing eleven short chapters. Part I (Chapters I-XI) is called " Explanatory treatment " and Part II (Chapters A–K) " Systematic treatment." The first part is written in conversational style with the emphasis on explanation and comment. The second part is compact, precise, complete in itself and characterized by economy of statement. The author starts from Peano's axioms for the system of whole numbers, defined as a succession of elements. A real number is defined as a set of equivalent Cauchy sequences of the elements of the ordered field of rational numbers and finally a complex number as an ordered pair of real numbers. There are, of course, other ways of developing the theme. In the last chapter of the first part, brief indication is given of alternative treatments. There is a good collection of examples, intended " not to test the industry and technique " of the reader but to help him to acquire familiarity with the ideas of the text. There is a key to the examples, a short bibliography and an index (in which, curiously enough, Peano's name does not appear).

This book, which presents important basic material in an attractive and convenient form, will be read by many undergraduate students of mathematics, and indeed by others interested in mathematics, including physicists.

M. R. HOPKINS.

METHODS OF MATHEMATICAL PHYSICS (Third Edition)

By Sir Harold and Lady Jeffreys

London : Cambridge University Press. Pp. 714. Price £4 4s.

This third edition of a book which is the most important single book on the applied mathematician's or theoretical physicist's shelves is produced six years after the second and ten years after the original.

The changes made in the third edition are less extensive than those incorporated in the second. The most substantial are in chapter 1 which now in the treatment of covering theorems and Riemann and Stieltjes integrals compares very favourably with the original and also includes (unfortunately as a note) an elementary proof by Besicovitch of the theorem of bounded convergence for Riemann integrals. If these changes were not an excellent end in themselves one might be forgiven a fleeting suspicion that they were aimed at producing a book as ubiquitous as the elliptic functions of chapter 25.

Other changes incorporated arise in the

derivation of Poisson's equation (and a discussion of the restrictions on the density) in chapter 6, a more detailed discussion for complex arguments of the Airy integral in 17.07, of asymptotic solutions of Green's type for complex argument in 17.13, 17.131 and the analytical continuation of solutions of the confluent hypergeometric equation in 23.05.

In short, the alterations are not extensive enough to " date " the earlier editions unduly but the authors are to be congratulated on their alterations which are all improvements. For my part, I would have preferred to see one further alteration, this time in the definition of the Bessel function $Kh_n(x)$. I cannot convince myself that the superiority of Heaviside's definition offsets the sheer volume of results available on Macdonald's definition, and conversion factors can be so trying on the temper.

L. HOWARTH.

ATOMIC PHYSICS

An Atomic Description of Physical Phenomena

By G. P. Harnwell and W. E. Stephens

London : McGraw-Hill Book Co. Inc. Pp. 401 + x. Price 60s.

This excellent book forces attention to the difficulties with which we contend when so many otherwise suitable books are prepared in terms of an altogether different educational system. *Atomic Physics* is based upon formal courses to first year graduate students, and in common with other books at this level probably makes too great demands of thought and maturity for all but the ablest third year undergraduates in our honours schools. One is tempted to think that very many, perhaps all, Ph.D. students in physics might profitably be required to master this book, or one like it, during their studentship, and perhaps even be examined upon it. But these particular students form only a part of the growing generation of physicists which certainly stands in need of a more solid grounding in the fundamentals of physics than can be expected from a three-year undergraduate course ending at about age twenty-one. This book offers an approach sufficiently novel and sufficiently mature to appeal to these.

Atomic Physics is not a reference book—no attempt has been made to sectionalize it for this purpose—it is clearly intended to be read systematically under a rather few main headings. In an attempt to pick out sections of particular interest, one may select the second chapter, " Atomic Nature of Matter and Radiation," the sixth, " Statistics of Atomic Processes," and the seventh, " Elementary Properties of Matter " : the order of these chapters is to be noted.

Chapter two is interesting for its stress upon the strict bases of the atomic constants and for the emphasis directed to their precision determination. Something of its quality is illustrated when the concept of radiation is introduced : " Radiation is essentially the term which is used to describe the mechanism through which a change in one charge configuration induces a change in another charge distribution." The two later chapters develop the idea of bulk matter through idealized systems (chapter 6) to more direct properties of matter (chapter 7). Throughout the explanatory sections are of conspicuous clarity; they range widely to make full use of a presumed sound background knowledge of physical phenomena. They cover attractively and illuminatingly a great deal of what is now centered on " solid state physics."

This is a book which can be strongly recommended. It covers ground, often arrestingly, of undoubted importance to most practising physicists.

J. G. WILSON.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON MARCH 20, 1956

An asterisk (*) indicates transfer from another grade

FELLOWS

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Williams, Edward Holman B., B.A, Research Physicist, Joseph Lucas (Electrical) Ltd., Birmingham.

28 Students and 11 Subscribers were also admitted.

Branch and Group News

London and Home Counties Branch : Visit to National Institute of Medical Research

Half-day visits to technical establishments are, because of their great popularity, becoming an important part of the Branch programme. The visit to the National Institute for Medical Research on Saturday, April 7, was unusual in two main respects : it took place on a day when most members are available and thus was more popular than usual (the first post after the issue of the notice produced more applications than there were vacancies). Secondly, it provided an opportunity new to most members, of studying the applications of physics to some of the fundamental problems of medical science.

Sir Charles Harington, the Director of the Institute, welcomed the party and explained in outline the work of his laboratories and their relation with the Medical Research Council and the World Health Organization. We were interested to learn, for instance, that besides its many research projects the Institute provides and assesses standards for many materials such as vitamins and insulin. It also operates an international influenza control centre by collaboration with laboratories in other countries.

A film depicting the freezing of living cells was then introduced by Dr. Audrey Smith. This technique, now of great commercial value for the artificial insemination of poultry and cattle, permits living cells and spermatozoa to be stored at temperatures of $-70°C$ for periods of up to two years.

The party then visited four of the departments of the Institute. In the Biochemistry Division gas chromatography was described and demonstrated. An essential part of this equipment is the highly ingenious and sensitive gas density bridge capable of detecting 1 part of certain organic vapours in the presence of 10^5 parts of nitrogen. The Biophysics Division showed new applications for the familiar techniques of radioactive tracers, mass spectrometry and ultra-violet phase-contrast microscopy. The study of the transmission of nerve impulses is the field of the Physiology Division and here the techniques of pulse stimulation were demonstrated. Finally we were able to study and discuss some of the specialized instruments developed at the Institute; we also saw the Institute's very fine library.

Our thanks are due to Sir Charles Harington and to Mr. W. C. Lister (*Fellow*) who made the detailed arrangements.

D. T. R. Dighton.

Education Group

Mr. G. W. Warren (*Fellow*) has now succeeded Dr. J. Topping as Chairman of the Group ; Mr. T. H. Tyler (*Associate*) has become Honorary Secretary in succession to Mr. F. Y. Poynton.

X-Ray Analysis Group

Prof. E. G. Cox (*Fellow*) has been elected Chairman in succession to Mr. H. P. Rooksby.

Midland Branch : Annual Dinner

The Third Annual Dinner of the Midland Branch was held on March 22, at the University Union, Edgbaston, Birmingham. Members and their ladies were received by the Chairman, Professor P. B. Moon, and by Mrs. Moon. After an excellent meal and the loyal toast, members were entertained by the principal guest, Dr. R. Beeching (*Fellow*), Chairman of I.C.I. Ltd. (Metals Division), who proposed the health of the Institute. On behalf of the Institute, the Chairman replied in his usual witty but informal manner. This informality has become a characteristic of all the Midland Branch meetings. After the toasts, members adjourned to the reception room for coffee and a talk by Mr. G. de Q. Robin (*Fellow*) entitled "Antarctic Walkabout, 1957." admirably illustrated with lantern slides. In thanking Mr. Robin the Chairman concluded a very pleasant evening.

Dr. R. Beeching (left) and Professor P. B. Moon.

R. J. WAKELIN.

Facing the camera (from left to right), Mrs. R. E. Bastick, Professor T. L. Ibbs, Dr. D. Parkinson, Mrs. Parkinson, Mr. C. H. Leigh-Dugmore, Mr. D. Charles.

The Institute's Journals

PRINCIPAL CONTENTS OF THE MAY, 1956, ISSUES

Journal of Scientific Instruments: Volume 33, No. 5

PAPERS

A large optical slit mechanism employing spring movements. By Prof. R. V. Jones, C.B., C.B.E., F.Inst.P. (*Natural Philosophy Department, University of Aberdeen*).

A spring layout is described for producing symmetrical movement in an optical slit 10 cm long, and capable of operating at any width between 5 and 1,000μ. Such factors as the parallelism and separation of the jaws are made independent of gravity by suitable arrangement of spring strength and disposition of centres of gravity of the moving members. The jaw edges are optically worked to confine width variations along the slit to about ±0·15μ r.m.s., and the jaws can be set parallel by eye and hand to within about 0·3μ variation in the 10 cm length.

A remotely-controlled traversing yawmeter for boundary-layer exploration. By D. W. Bryer (*National Physical Laboratory, Teddington, Middlesex*).

The report describes a remotely-controlled yawmeter traversing apparatus which has been constructed at the National Physical Laboratory. A high degree of accuracy, 0·001 in. in traverse and 0·05° in rotation, together with rapid operation and direct indication of position, is achieved by mounting the yawmeter on a micrometer mechanism which is controlled through flexible drives by reversible motors incorporating revolution counters. Details are given of the design, which includes safety devices and a system whereby the traverse is related to an accurate datum position.

Two designs for a paramagnetic oxygen meter. By A. Hobson, A.Inst.P. (*Department of Physical Research, Admiralty Research Laboratory, Teddington, Middlesex*), and R. H. Kay, A.Inst.P. (*The University Laboratory of Physiology, Oxford*).

A robust oxygen detector capable of giving direct readings on a meter or recorder has many applications in physiology or in the control of chemical processes. Physical methods at present available commercially have characteristics which often make them unsuitable for particular applications. This paper describes two separate but parallel investigations of the design of an oxygen meter depending on the paramagnetism of oxygen and the change of its susceptibility with temperature. One instrument covers 0–100% oxygen concentrations at or near atmospheric pressure, the other 90–170 mm of mercury partial pressure of oxygen in total ambient pressures of about 600–900 mm of mercury.

A Pirani gauge for operation up to a pressure of 10mm of mercury. By J. H. Leck and C. S. Martin (*University of Liverpool*).

A modified Pirani gauge is described which makes the continuous reading gauge useful in the high pressure range without requiring a great rise in the wire temperature. It is well known that a reduction of the length of the hot wire increases the useful range but at the same time decreases the sensitivity. It is shown here that an adequate sensitivity, combined with a large range, can be obtained by placing artificial supports along the length of the wire so as to give, in effect, a large number of short wires in series. In this way a gauge useful up to a pressure of 10 mm of mercury with a wire temperature of only 50°C, can be designed.

A modified bridge earthing device. By B. Berger (*C. A. Parsons Co. Ltd., Newcastle upon Tyne, 6*).

A method is described for eliminating the effects of stray impedance in an a.c. Wheatstone bridge. Whereas the Wagner earthing device uses two auxiliary branches, the modified device uses an auxiliary source of supply. The elimination of the auxiliary impedances is of advantage in a high-voltage bridge.
Brief practical details of the device are given for a 50 c/s Schering bridge. The device is used to study the influence of stray capacities when such a bridge is applied to a transformer manufacture process.

An oxygen-quenched Geiger-Müller counter. By D. Srdoc (*The Ruder Boskovic Institute, Zagreb, Yugoslavia*).

Systematic investigations have been made to determine the best concentrations of mixtures of neon, argon and oxygen for filling self-quenching Geiger-Müller counters. Evidence is given of the quenching action of oxygen in mixtures with neon and argon. The life of such counters seems to be unlimited. A plateau 65 V wide with a 15% slope per 100 V has been obtained at $V_{op} = 400$ V. Cathodes of various materials have been used and it was found that copper, brass and aluminium, coated with colloidal graphite, are quite satisfactory. This is an advantage relating to halogen-quenched Geiger-Müller counters.

An input amplifier for a pulse-height analyser. By A. Folkierski (*Imperial College of Science and Technology, London*).

The design described incorporates two facilities important in the study of γ-ray spectra. Firstly, the analyser can be gated by pulses occurring simultaneously with the pulses to be measured. Secondly, the scale can be expanded. Errors introduced by the gate do not exceed 1% of the maximum output pulse-height.

A remote control apparatus for the movement of dosage measuring or similar equipment to indicated positions. By B. J. Perry and N. H. Pierce (*Westminster Hospital, London*).

The mechanical and electrical features of this apparatus are described, with particular reference to ease and cost of construction. The relation of mechanical and electrical backlash to the accuracy of the whole system is discussed, and it is shown that some electrical backlash is essential in this simple type of servo-system. Its relation to position setting backlash and minimum inching distance is indicated.

Fine grain development in xerography. By K. A. Metcalfe and R. J. Wright (*Defence Standards Laboratories, Woodville, South Australia*).

Electrostatic images on xerographic plates may be developed by electrophoretic deposition from simply prepared suspensions of powders in certain high resistivity liquids. Prior milling of the powders in the liquids or in dispersing agents results in finer-grained developers. Virtually grainless images should be obtainable by development in colloidal suspensions.

A switch-dial potential divider. By W. K. Clothier (*Commonwealth Scientific and Industrial Research Organization, Chippendale, New South Wales, Australia*).

A new potential divider network is shown to represent a general class of divider of which the Varley slide is a special case. Another special case of particular interest is one in which the resistances of all dials are the same. In a decade divider of this type with a total resistance $10r$, only three values of resistance coil r, $r/9$ and $8r/9$ are required, or two values if the r's are made up from series pairs of $r/9$ and $8r/9$ coils. Since the errors due to contact resistance are small, the circuit is especially suitable for low-resistance dividers.

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SPECIAL ARTICLE

The physical meaning of indentation and scratch hardness. By D. Tabor (*Research Laboratory on the Physics and Chemistry of Surfaces, Department of Physical Chemistry, Cambridge*).

A study of the plastic deformation of metals by hard indenters shows that the indentation hardness is essentially a measure of the plastic yield stress of the metal. With pyramidal (and conical) indenters the hardness, because of geometric similarity, is independent of the size of the indentation. With spherical indenters this is not so, the hardness increasing with size of indentation. From the increase in hardness with load, a semi-quantitative estimate may be made of the work-hardening characteristics of the metal. In the scratching and indentation of brittle solids such as minerals it is shown that the high hydrostatic pressures developed around the deformed region are often sufficient to inhibit brittle fracture. Under these conditions the deformation is primarily plastic. For this reason there is fairly good correlation between indentation and scratch hardness since both are essentially a measure of the plastic and not the brittle properties of the solid. From this approach it is possible to provide a physical basis for Mohs' scratch-hardness scale and to show that, excluding diamond, there is a reasonable " equality of intervals " between each number on the scale.

Papers

A re-determination of the equal-loudness relations for pure tones. By D. W. Robinson and R. S. Dadson (*National Physical Laboratory, Teddington, Middlesex*).

The paper describes a new determination of the equal-loudness relations for pure tones in free-field conditions which has been carried out at the National Physical Laboratory as a result of requests from organizations interested in various aspects of the acoustics of hearing. The equal-loudness contours are of considerable importance in this field, being fundamental to a proper understanding of aural judgments of the loudness of sounds of all kinds. They are also concerned in numerous practical applications in the study of noise.

The first set of contours for free-field conditions was given by Fletcher and Munson in 1933, and a second determination was carried out by Churcher and King in 1937, but these two investigations showed considerable discrepancies over parts of the auditory diagram. The present work has been carried out on a more extensive scale, using a large team of otologically normal persons, and new techniques have been introduced enabling reliable measurements to be made over a wider range of intensity than has hitherto been possible.

The new results cover a range of frequency of from 25 to 15,000 c/s and of sound pressure level up to about 130 dB relative to 0·0002 dyn/cm^2. The data show a greater degree of regularity than the former results, and allow the equivalent loudness of a pure tone of any frequency to be expressed by formulae quadratic in the sound pressure level, the coefficients varying smoothly with frequency. The results include a new determination of the normal threshold of hearing in free field, which is highly consistent with the equal-loudness contours. At frequencies above 1,000 c/s account needs to be taken of variations due to the age of the observers, which become of particular importance at the upper end of the frequency range.

The new results have indicated the causes of some of the discordant features in the earlier determinations and it is hoped that the work will facilitate agreement on a standard set of equal-loudness contours. On account of its relevance to noise measurement, some extension to equal-loudness relations for bands of noise is being undertaken.

The spectral quantum- and energy-efficiency of calcium tungstate X-ray intensifying screens. By R. H. Herz, F.Inst.P. (*Kodak Ltd., Harrow, Middlesex*).

The intensifying action of calcium tungstate screens in combination with X-ray film has been investigated over a wide range of X-ray wavelengths equivalent to X-rays generated with energies of between 40–1,200 kV. By means of the evaluation of the quantum- and energy-efficiencies of screen and film an understanding of their behaviour, i.e. their utilization of energy within this range of quantum energies, is obtained.

The production of transparent profiles of dust particles as an aid to automatized particle counting. By R. J. Hamilton, A.Inst.P., and B. A. Phelps (*National Coal Board, Mining Research Establishment, Isleworth, Middlesex*).

The technique of " shadowing " by metal evaporation in a vacuum has been adapted to the production of plane " negative " images of dust deposits on microscope slides at natural size by vacuum evaporation of metal at right angles to the slide, and subsequent removal of the dust. The slide receives a precise impression of the geometric projections of the particles. The correspondence of image and object is exact. The thickness of the deposited film can be suited to the contrast requirements of an automatic particle counter; further, the film lies in one plane and is only a few hundred Ångström units thick. Many of the optical problems arising from the association of automatic counting techniques with high power light microscopy, namely, depth of focus and variable contrast between particles and background and between different parts of single particles, are avoided by substituting the shadow for the original specimen, as suggested by Whitaker.

Measurement of the half-life of radon with a Curie-type ionization chamber. By P. C. Marin (*Clarendon Laboratory, Oxford*).

An improved version of the Curie-type ionization chamber enables an accurate comparison to be made of the ionization currents produced by γ-rays. The ionization current produced by 1 mc of radium can be measured with an accuracy of 0·02%. The linearity of response of this instrument has been investigated for radon sources up to 250 mc, with an argon gas filling.

The half-life of radon measured in this way was found to be 3·8229 ± 0·00027 days.

A photoelastic method of two-dimensional separation of stresses along a line of symmetry by using the isochromatic fringes only. By S. P. Christodoulides (*University College, London*).

Examination of the general equations of equilibrium in curvilinear co-ordinates for a two-dimensional model shows that when these are applied to points on an axis of symmetry, the isochromatics and their orthogonals being taken as axes of co-ordinates, an equation of the same form as the Lamé-Maxwell equations is obtained, and this leads to a method of separating the stresses on an axis of symmetry by the use of the isochromatic fringes only.